U. S. DEPARTMENT OF COMMERCE

# BUILDING MATERIALS AND STRUCTURES

REPORT BMS68

## Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 3

*by*

PERCY A. SIGLER

*and* ELMER A. KOERNER



NATIONAL
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# Foreword

Various installations of floor coverings have been subjected to performance tests at the National Bureau of Standards as part of a research program on building materials suitable for low-cost house construction. Technical information of their relative ability to withstand service should be of aid to consumers and to installers in selecting floor coverings and methods of installation to meet various flooring problems.

This report presents the results of a test on a third series of 40 installations in the Bureau's floor-testing chamber, as a supplement to reports BMS34 and BMS43.

LYMAN J. BRIGGS, *Director.*

# Performance Test of Floor Coverings for Use In Low-Cost Housing: Part 3

*By* PERCY A. SIGLER *and* ELMER A. KOERNER

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ABSTRACT

A performance test was conducted in the floor-testing chamber of the National Bureau of Standards on a third series of 40 test installations. Included in the test were linoleums in sheet and tile form, cork-composition tile, sheet rubber, rubber tile, asphalt tiles, fiberboard tiles, felt-base floor coverings having various wearing surfaces, three monolithic floors, and a number of wood floors. The bonding agents used included lignin pastes, cumar-resin cement, alumina cement-latex paste, rubber cements, various asphaltic adhesives, and nails. Installations were made on concrete, strip-wood, and plywood subfloors. Installations on strip-wood subfloors were made with underlays of dry and asphalt-saturated lining felts. Descriptions of the testing equipment and test installations are given. Results showing the relative depth of the depressions in the floor coverings during the test are presented in tables. Brief summaries of the manner in which the various test installations performed are given, and photographs of the test panels after 48,000 cycles of the testing equipment are shown.

## I. INTRODUCTION

There are Federal specifications for a number of nontextile floor coverings which can be used as a basis for securing good-quality merchandise of a particular type [1].[1] Comparable information on the different types is of direct and economic interest to the consumer in selecting a floor covering to meet his particular need. In order to provide technical information of this nature, studies of some of the important properties of floor coverings have been made at the National Bureau of Standards in connection with a general research program on building materials and structures.

One phase of these studies consisted of laboratory performance tests of various installations of floor coverings. Lack of information on such important factors as quality of merchandise, condition of subfloor, extent of maintenance, and magnitude of exposure make direct comparisons in service difficult. In these performance tests it was possible to control many of the factors affecting performance in service. However, it was not found possible to include all such factors. No attempt was made to ascertain the effects of finishing coats, maintenance, age, and atmospheric conditions.

This report presents the results of a performance test on a third series of 40 installations in the Bureau's floor-testing chamber. The results obtained on the two previous series of installations were published in reports BMS34

[1] Figures in brackets refer to the list of selected references at the end of this paper.

and BMS43 [2, 3]. Included in report BMS34 are the results of tests on several kinds of linoleum, felt-base floor coverings with various wearing surfaces, pressed fiberboard, and strip-wood floors of maple, white oak, and yellow pine. Report BMS43 contains the results of tests on battleship linoleum, rubber in sheet and tile form, felt-base floor coverings with different wearing surfaces, magnesium-oxychloride monolithic floors, a cement-latex monolithic floor, and asphalt tiles of various compositions. The only alteration in the equipment used in the three performance tests was the substitution of a rubber-tired truck wheel in the second and third tests for one of the two steel-rimmed truck wheels used in the first test.

In order to obtain results within a comparatively short time, a laboratory test must necessarily be accelerated and severe. The testing equipment was a modification of that previously used in a study of industrial-type floors [4]. The materials tested represented good-quality merchandise in their respective fields. The generous cooperation of various manufacturers in furnishing materials for test is gratefully acknowledged.

Other laboratory investigations have been conducted on various floor coverings and adhesives to determine their relative merits with respect to specific properties. The results obtained in some of these investigations have been published [5, 6].

## II. FLOOR-TESTING CHAMBER AND EQUIPMENT

The floor-testing chamber contains a concrete circular track 4 ft wide, 8½ in. thick, and approximately 40 ft in diameter, with a metal-shod concrete curb on each side. The circular track is divided into 20 test spaces by metal thresholds, the surfaces of which are 4 in. above the structural slab. Wood or concrete subfloors and the various floor coverings were installed in these test spaces. Two different installations, 3 ft long, were made in each test space.

Figures 1 and 2 show portions of the circular track and the testing equipment used in this performance test. The principal features of the equipment were a "walking wheel", *G* (fig. 1), a platform truck, *A*, and two casters, *E* and *F* (fig. 2).

The equipment was propelled around the track at about 2 miles an hour by the walking wheel, which was 4 ft in diameter and carried a load of approximately 275 lb. The wheel was shod with eight wooden blocks, *H* (fig. 1), 6 by 13 by 1½ in., which were covered with a cushioning layer of rubber ¼ in. thick and a wearing surface of leather ¼ in. thick. This arrangement produced a bumping and slipping action between the wheel and the floor coverings and imitated, to some extent, a walking action. During the second half of the test, No. 3 grit garnet cloth was placed over the eight leather-surfaced shoes in order to accelerate the abrasive action. The average slippage of the walking wheel during the test was approximately 1 percent.

The platform truck was equipped with two wheels of 12-in. diameter. The inner wheel, *B* (fig. 1), had a solid rubber tire, 2½ in. wide, and carried a load of approximately 500 lb. The outer wheel had a slightly crowned steel rim, 3 in. wide, and carried a load of approximately 600 lb.

On the front of the truck were mounted two lever mechanisms, *C* (fig. 2). A swivel steel-wheel caster, *E*, of 2-in. diameter and ⅞-in. width, was attached to one of the levers and exerted a force of 20 lb normal to the floor. A steel-ball caster, *F*, of 1-in. diameter, was attached to the other lever and exerted a force of 10 lb normal to the floor. Helical springs, *D*, were used for applying the loads on the casters.

The number of cycles around the track made by the testing equipment was recorded by a counter, *R* (fig. 1), mounted at the side of the track and operated by an arm attached to the truck. A dial depth gage, *S* (fig. 2), was used to measure the depressions made in the floor coverings by the equipment. The depth gage had a span of 8 in. and was equipped with a flat-ended foot of ⅛-in. diameter. The foot exerted a pressure of 20 lb/in$^2$.

## III. TEST CONDITIONS AND PROCEDURE

With a few exceptions, the concrete subfloors used in this performance test were the same

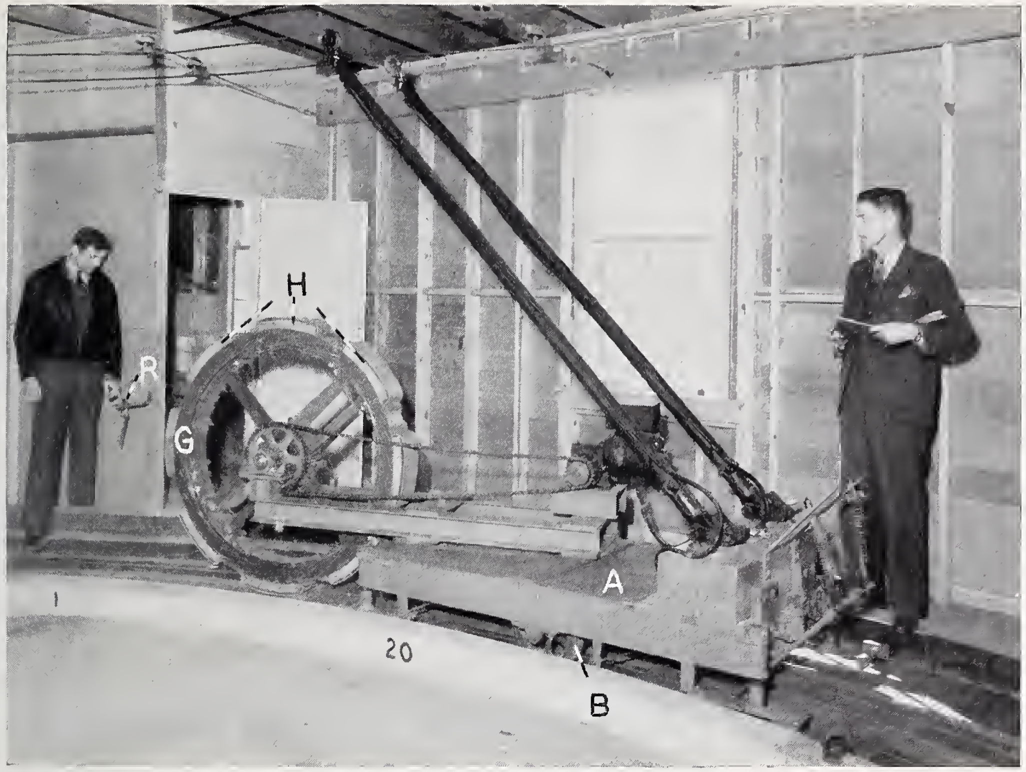


FIGURE 1.—*Side view of testing equipment.*

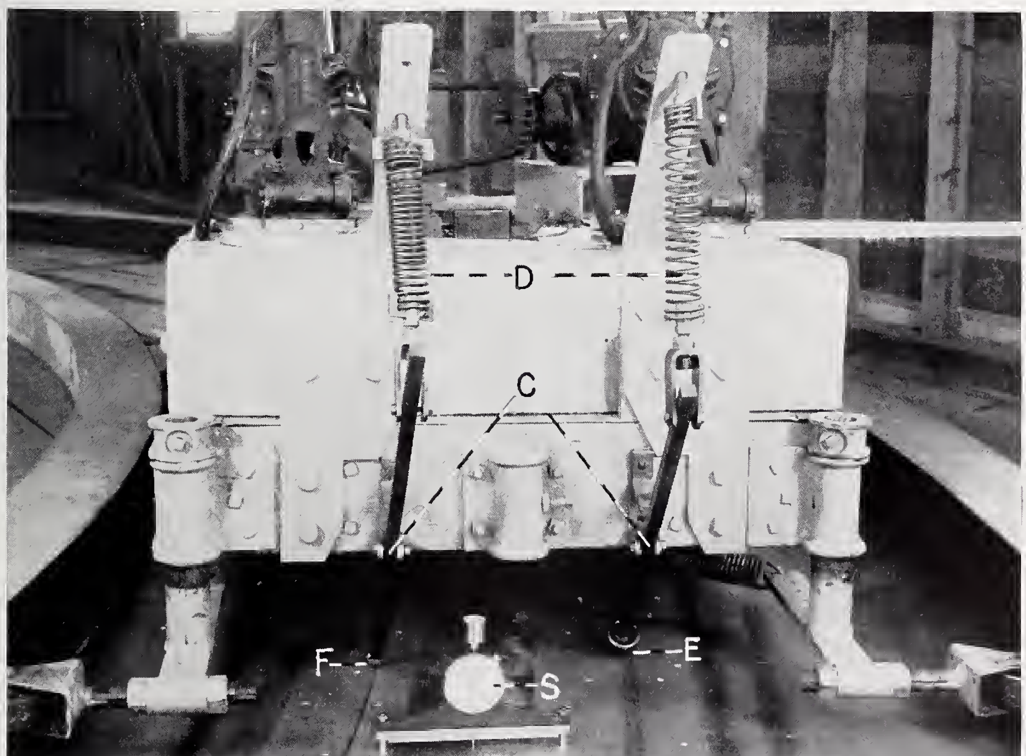


FIGURE 2.—*Front view of testing equipment and depth gage.*

subfloors used in the two previous tests. The concrete consisted of 1 part of cement, 3 parts of sand, and 4 parts of gravel, by weight. The surface of the concrete had a steel-troweled finish and was thoroughly cleaned before installing the new floor coverings. New wood subfloors were installed and consisted of either tongued-and-grooved strip flooring or plywood. The strip flooring was blind-nailed with 8d cut nails to four wooden sleepers spaced 12 in. on centers. The sleepers were approximately parallel to the direction of travel of the truck and were embedded in concrete. The plywood was face-nailed to the sleepers, at intervals of 6 in., with 6d barbed and rosin-coated box nails.

The floor coverings were installed during July and August of 1939. Atmospheric conditions in the testing chamber during the installations ranged from 55 to 75 percent in relative humidity and from 70° to 90° F in temperature. A setting-up period of at least 2 weeks was allowed before starting the test. The performance test was started on September 11, 1939, and was stopped on March 19, 1940, after 48,000 cycles of the testing equipment. Atmospheric conditions in the testing chamber during the test ranged from 50 to 75 percent in relative humidity and from 30° to 85° F in temperature. The floor coverings were swept at least once every 500 cycles of the equipment, so that any effect on the results of loose particles from other test floors was negligible.

The floor coverings were subjected to 50 cycles of the testing equipment, after which reference marks of white enamel were placed at intervals beside the paths made by the walking wheel and the two truck wheels. Initial depth measurements were recorded for use in determining the depth of compression and wear caused by the equipment. On each of the 40 installations, 5 measurements were taken along each of the three paths, making a total of 600 readings. These measurements were repeated at 4,000, 10,000, 20,000, 24,000, 30,000, 40,000, and 48,000 cycles of the equipment. During the first 24,000 cycles the eight shoes of the walking wheel were surfaced with strips of leather belting, 6 in. wide. During the second 24,000 cycles the leather-covered shoes were surfaced with strips of No. 3 grit garnet cloth, 6 in. wide, which were replaced with new strips every 2,000 cycles. At the end of the test the floors were washed with soap and water and then photographed. In taking the photographs, a spot light, with the rays at an angle of approximately 45 degrees with the surface of the track, was used as a source of light in order to more clearly show any fractures or blisters in the floor coverings.

## IV. DESCRIPTION OF TEST INSTALLATIONS

The 40 test installations in this performance test involved 26 different floor coverings and 11 different adhesives. With a few exceptions, specimens of each floor covering were installed on both a concrete and a wood subfloor. An outline of the test installations is given in table 1.

## V. RESULTS

The depths of the depressions in the floor coverings made by the two truck wheels and the walking wheel, at different stages of the performance test, are recorded in table 1.

In general, the rubber-tired truck wheel caused very little damage to the floor coverings and bonding agents. The steel-tired truck wheel, however, caused failures ranging from small fractures or blisters in some of the floor coverings to complete crushing or separation from the subfloor of others. Many of the floor coverings were indented to an appreciable degree by the action of the steel-tired truck wheel. For the same floor covering the depressions were much greater on a wood subfloor than on a concrete subfloor. This was due to the compression and permanent deformation of the wood subfloors and to the compression of the felt underlays where used.

The depressions in the floor coverings caused by 24,000 cycles of the walking wheel surfaced with leather appeared to result principally from compression rather than wear. With a few exceptions the depths of the depressions were small. The average amount each floor covering was worn by 24,000 cycles of the walking wheel surfaced with abrasive cloth is shown in table 2. The averages were computed from the differences in the depths of

TABLE 1.—*Test installations and results of measurements for depth of compression and wear*

| Test panel [a] | Subfloor | Underlay | Bonding agent | Floor covering: Type and description [b] | Floor covering: Nominal thickness | Average depth of depression made by— Rubber-tired truck wheel: 10,000 cycles | Rubber-tired truck wheel: 48,000 cycles | Steel-tired truck wheel: 10,000 cycles | Steel-tired truck wheel: 48,000 cycles | Walking wheel: 24,000 cycles | Walking wheel: 48,000 cycles |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *in.* | *in.* | *in.* | *in.* | *in.* | *in.* | *in.* |
| *1L* | Concrete | None | Resin cement, cumar resin. | Marbleized linoleum; marbleized pattern, white. | 1/8 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.010 |
| *2L* | Strip wood [c] | Lining felt [d] | Lignin paste | do | 1/8 | .002 | .005 | .008 | .034 | .005 | .011 |
| *1R* | Concrete | None | do | Marbleized linoleum; marbleized pattern, tan. | 1/8 | .000 | .000 | .000 | .002 | .000 | .001 |
| *2R* | Strip wood [c] | Lining felt [e] | do | do | 1/8 | .000 | .000 | .005 | .017 | .001 | .002 |
| *3R* | Concrete | None | do | Linoleum tile;[f] marbleized pattern, mahogany; burlap backing. | 1/8 | .000 | .000 | .000 | .003 | .000 | .002 |
| *4R* | Strip wood [c] | Lining felt [e] | do | do [f] | 1/8 | .000 | .000 | .005 | .014 | .001 | .004 |
| *3L* | Concrete | None | do | Cork-composition tile:[g] plain pattern, gray; no fabric backing. | 1/8 | .000 | .000 | .001 | ([h]) | .000 | .001 |
| *4L* | Strip wood [c] | Lining felt [e] | do | do [g] | 1/8 | .000 | .000 | .006 | .018 | .001 | .002 |
| *5L* | Concrete | None | Cut-back rubber cement. | Sheet rubber; marbleized pattern brown. | 1/8 | .000 | .000 | .000 | .000 | .001 | .005 |
| *5R* | do | do | Rubber dispersion, soap type. | Rubber tile;[g] marbleized pattern, gray. | 1/8 | .000 | .000 | .000 | .001 | .000 | .006 |
| *6L* | do | do | Alumina cement-latex paste. | Jaspe linoleum; jaspe pattern, brown. | 3/32 | .000 | .000 | .003 | .009 | 001 | .006 |
| *6R* | do | do | do | Felt base; printed pattern, lavender; wearing surface, enamel. | 5/64 | .000 | .000 | .008 | .021 | .001 | .009 |
| *7R* | do | do | Lignin paste | Felt base; printed pattern, red; wearing surface, enamel. | 5/64 | .000 | .001 | .006 | .023 | .000 | .010 |
| *8L* | Plywood [i] | do | do | do | 5/64 | .001 | .001 | .011 | .043 | .002 | .013 |
| *7L* | Concrete | do | do | Felt base; mottled pattern, white; wearing surface, resin-treated cotton-linters sheet duplexed to felt backing. | 5/64 | .000 | .001 | .003 | .007 | .001 | .003 |
| *8R* | Plywood [i] | do | do | do | 5/64 | .000 | .000 | .010 | .040 | .002 | .004 |
| *9L* | Concrete | do | do | Felt-base tile;[g] jaspe pattern, brown; wearing surface, cellulose nitrate composition. | 5/64 | .001 | .000 | .005 | .012 | .002 | .003 |
| *10L* | Strip wood [c] | Lining felt [j] | do | do [g] | 5/64 | .004 | .004 | .015 | .041 | .006 | .008 |
| *9R* | Concrete | None | Cut-back rubber cement. | Felt-base tile;[g] jaspe pattern, green; wearing surface, cellulose nitrate composition. | 7/64 | .001 | .001 | .007 | .016 | .002 | .004 |
| *10R* | Strip wood [c] | do | Lignin paste | do [g] | 7/64 | .001 | .001 | .009 | .030 | .001 | .004 |
| *11L* | Concrete | do | Alumina cement-latex paste. | Asphalt tile; [g] plain pattern, green; 1-minute indentation, 0.010 in.[k] | 1/8 | .000 | .000 | .002 | .025 | .000 | .018 |
| *11R* | do [l] | do | Asphalt emulsion, soap type. | do [g] [k] | 1/8 | .000 | .000 | .005 | .018 | .000 | .018 |
| *12L* | Plywood [i] | do | Alumina cement-latex paste. | do [g] [k] | 1/8 | .000 | .000 | .010 | ([h]) | .003 | .024 |
| *12R* | do [i] | do | Asphalt emulsion, soap type. | do [g] [k] | 1/8 | .002 | .002 | .012 | .128 | .003 | .017 |
| *13L* | Concrete [l] | do | do | Asphalt tile; [g] plain pattern, green; 1-minute indentation, 0.012 in. [k] | 3/16 | .000 | .000 | .004 | .044 | .001 | .019 |
| *14L* | Strip wood [c] | Lining felt [e] | do | do [g] [k] | 3/16 | .001 | .001 | .006 | .125 | .001 | .011 |
| *13R* | Concrete [l] | None | do | Asphalt tile; [g] plain pattern, red; 1-minute indentation, 0.010 in. [k] | 3/16 | .001 | .001 | .004 | .024 | .002 | .012 |
| 14*R* | Strip wood [c] | Lining felt [e] | do | do [g] [k] | 3/16 | .000 | .001 | .007 | .061 | .001 | .010 |
| *15L* | Concrete | None | Cut-back asphalt | Asphalt-impregnated fiberboard tile; [m] plain pattern, green and red. | 1/4 | .003 | .003 | .018 | .115 | .005 | .030 |
| *16R* | Plywood [n] | do | do | do [m] | 1/4 | .008 | .010 | .016 | ([h]) | .003 | .062 |
| *15R* | Concrete [l] | do | do | Asphalt-impregnated fiberboard tile; [m] plain pattern, dull black. | 1/4 | .003 | .003 | .015 | .066 | .006 | .039 |
| *16L* | Wood sleepers. | do | Blind-nailed, 8d cut nails. | Strip Douglas fir;[o] B and better grade, edge-grained, flat-back; density, 27 $lb/ft^3$ [p] | 25/32 | .000 | .000 | .011 | .064 | .001 | .034 |
| *17L* | Concrete [l] | do | Warm asphalt | White-oak unit-block; [o] [q] flat-grained, two metal splines on back. | 1/2 | ([s]) | [s].001 | ([s]) | [s].025 | ([s]) | [s].005 |
| *18L* | Strip wood [c] | Asphalt-laminated sheathing paper. | Blind-nailed, 4d casing nails. | Red-oak unit-block; [r] [q] flat-grained, two metal splines on back. | 1/2 | ([s]) | [s].001 | ([s]) | [s].028 | ([s]) | [s].007 |
| *17R* | Concrete [l] | None | Hot asphalt | Rock-elm plywood tile; [r] [t] 3-ply, tongued-and-grooved. | 1/2 | ([s]) | [s].001 | ([s]) | [s].031 | ([s]) | [s].005 |

For footnotes, see end of table.

| Test panel | Subfloor | Underlay | Bonding agent | Floor covering: Type and description | Floor covering: Nominal thickness | Average depth of depression made by— Rubber-tired truck wheel: 10,000 cycles | Rubber-tired truck wheel: 48,000 cycles | Steel-tired truck wheel: 10,000 cycles | Steel-tired truck wheel: 48,000 cycles | Walking wheel: 24,000 cycles | Walking wheel: 48,000 cycles |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *in.* | *in.* | *in.* | *in.* | *in.* | *in.* | *in.* |
| *18R* | Strip wood[c] | ¼-in. sisal-fiber mat, rubberized. | None | Rock-elm plywood tile;[r t] 3-ply, tiles joined together with metal dowel pins. | ⅜ | ([s]) | [s].003 | ([s]) | [s].017 | ([s]) | [s].011 |
| *19L* | do[c] | None | Face-nailed, 6d box nails. | Douglas-fir plywood;[o] 5-ply | ½ | .000 | .000 | .015 | .046 | .001 | .009 |
| *19R* | do[c] | Asphalt-impregnated sheating paper. | Floor covering as installed. | Magnesium-oxychloride composition reinforced with expanded metal; plain pattern, green; aggregate, granite dust; density, 118 lb/ft,[3] [p] crushing strength, 9,400 lb/in.[2] | ½ | .001 | .003 | .003 | .039 | .002 | .014 |
| *20R* | Concrete[u] | None | do | Alumina cement-latex composition; plain pattern, dark gray; aggregate, ground cork and silica; density, 61 lb/ft[3] [p]. | ½ | .009 | .013 | .019 | .037 | .014 | .040 |
| *20L* | do[u] | do | do | 1:2 cement-mortar topping; aggregate, Potomac-river sand; cement-water ratio, 2⅓; interval between placing and troweling, 3½ hr.; damp-cured for 6 days; density, 137 lb/ft;[3] [p] crushing strength, 8,800 lb/in.[2] | 1 | .000 | .000 | .002 | .011 | .001 | .011 |

[a] *L*=left half of panel; *R*=right half of panel (facing the panels from the inside of the circular track).
[b] Color listed is the predominating color.
[c] Edge-grained Douglas fir, 25/32 in. thick, with a 2⅜ in. face.
[d] 1 lb/yd² dry lining felt bonded to subfloor with lignin paste.
[e] 1½ lb/yd² asphalt-saturated lining felt bonded to subfloor with lignin paste.
[f] Size of tile, 8¾ by 8¾ in.
[g] Size of tile, 9 by 9 in.
[h] Floor covering was too severely damaged to measure accurately.
[i] Douglas fir plywood, ¾ in. thick, 5-ply.
[j] ¾ lb/yd² dry lining felt bonded to subfloor with lignin paste.
[k] Method prescribed in Federal Specification SS-T-306, Tile; Asphalt.
[l] Subfloor given a priming coat of cut-back asphalt primer.
[m] Size of tile, 12 by 24 in.
[n] Douglas fir plywood, ½ in. thick, 5-ply.
[o] Surface given one heavy coat of a sealer.
[p] At 65-percent relative humidity and 72° F temperature.
[q] Size of unit-block 10 by 10 in.
[r] Surface had a factory-applied finish.
[s] Accuracy of depth-gage measurements was questionable due to slight warping or displacement of floor covering. Measurements reported were made with either a micrometer or a straight edge and feeler gage after removal of the floor covering.
[t] Size of tile, 8½ by 17 in.
[u] Surface had a broom finish.

compression and wear at 24,000 and 48,000 cycles given in table 1.

With a few exceptions the ball and roller casters caused very little damage to the floor coverings.

The accompanying photographs, figures 3 to 42, show the general condition of the floor coverings at the end of the test. The five paths shown in the photographs are, from left to right, those made by the rubber-tired truck wheel, the steel-ball caster, the walking wheel, the steel-wheel caster, and the steel-tired truck wheel. The small white dots in the photographs are the white-enamel reference marks.

## VI. SUMMARY

Brief summaries of the manner in which the various test installations performed are herewith presented.

The ⅛-in. marbleized linoleums, panels *1L*, *2L*, *1R*, and *2R*, showed very good performance, with the possible exception of panel *2L* (see figs. 3, 4, 5, and 6). In panel *2L* a dry lining felt was used over the strip-wood subfloor. The action of the steel-tired truck wheel caused the dry lining felt to laminate, resulting in an appreciable fracture of the linoleum (see figure 4). In panel *2R*, where an asphalt-saturated

Table 2.—*Average wear of floor coverings caused by 24,000 cycles of the "walking wheel" surfaced with abrasive cloth* [a]

| Floor covering [b] | Average depth of wear |
|---|---|
| | *in.* |
| Marbleized linoleum; 1/8 in.; white | 0.008 |
| Marbleized linoleum; 1/8 in.; tan | .001 |
| Linoleum tile; 1/8 in.; mahogany | .002 |
| Cork-composition title; 1/8 in.; gray | .001 |
| Sheet rubber; 1/8 in.; brown | .004 |
| Rubber tile; 1/8 in.; gray | .006 |
| Jaspe linoleum; 3/32 in.; brown | .005 |
| Felt base; 5/64 in.; lavender; wearing surface, enamel | .008 |
| Felt base; 5/64 in.; red; wearing surface, enamel | .010 |
| Felt base; 5/64 in.; white; wearing surface, resin-treated cotton-linters sheet | .002 |
| Felt-base tile; 5/64 in.; brown; wearing surface, cellulose nitrate composition | .001 |
| Felt-base tile; 7/64 in.; green; wearing surface, cellulose nitrate composition | .002 |
| Asphalt tile; 1/8 in.; green | .018 |
| Asphalt tile; 3/16 in.; green | .014 |
| Asphalt tile; 3/16 in.; red | .009 |
| Asphalt-impregnated fiberboard tile; 1/4 in.; green and red | .042 |
| Asphalt-impregnated fiberboard tile; 1/4 in.; dull black | .033 |
| Strip Douglas fir; 25/32 in.; edge-grained | .033 |
| White-oak unit-block; 1/2 in.; flat-grained | .005 |
| Red-oak unit-block; 1/2 in.; flat-grained | .007 |
| Rock-elm plywood tile; 1/2 in.; 3-ply | .005 |
| Rock-elm plywood tile; 3/8 in.; 3-ply | .011 |
| Douglas-fir plywood; 1/2 in.; 5-ply | .008 |
| Magnesium-oxychloride composition; 1/2 in.; green | .012 |
| Alumina cement-latex composition; 1/2 in.; gray | .026 |
| 1:2 cement-mortar topping; 1 in | .010 |

[a] The relative value of a floor covering should not be based entirely on resistance to wear. Other factors should also be considered, such as cost, indentation characteristics, ease of maintenance, adherence to subfloors, resistance to tear and fracture, etc.

[b] See table 1 for detailed description.

lining felt was used, there was no evidence of separation in the felt and the steel-tired truck wheel caused only slight fracture of the linoleum (see figure 6). The tan marbleized linoleum showed better resistance to abrasion than the white marbleized linoleum (see table 2).

The 1/8-in. linoleum tile, panels *3R* and *4R*, gave very good performance, particularly with reference to abrasion (see figs. 7 and 8). On a concrete subfloor the tiles were fractured slightly by the steel-tired truck wheel.

The 1/8-in. cork-composition tile, panels *3L* and *4L*, showed good performance except under the action of the steel-tired truck wheel, which fractured the tiles considerably (see figs. 9 and 10). On a concrete subfloor, panel *3L*, tiles along the path of the steel-tired truck wheel showed failure in bond and were fractured at an early stage of the test. They were replaced with new tiles at 1,240 cycles, which proved to be equally unsatisfactory. The tiles showed good resistance to abrasion.

The 1/8-in. sheet rubber and the 1/8-in. rubber tile used in this performance test were additional portions of samples used in a previous performance test [3]. These floor coverings on a concrete subfloor, panels *5L* and *5R*, gave very good performance. Along the path of the steel-tired truck wheel there were small welts in the floor coverings, caused by accumulations of the adhesives (see figs. 11 and 12). The sheet rubber showed slightly better resistance to abrasion than the rubber tile (see table 2 in this report and table 2 in report BMS43).

The jaspe linoleum, panel *6L*, was an additional portion of a sample used in a previous performance test [2]. In the previous test, extensive failures in adhesion to the subfloors occurred at an early stage of the test and the linoleum was in unserviceable condition at the end of the test. In the present test, with a different adhesive, there was no evidence of failure in bond and the floor covering showed good performance (see fig. 13).

The felt-base floor coverings with a wearing surface of enamel, panels *6R*, *7R*, and *8L*, gave fair performance considering the type of service for which they are designed. The floor coverings were in unserviceable condition at the end of the test (see figs. 14, 15, and 16). On a Douglas fir plywood subfloor, panel *8L*, the steel-tired truck wheel caused considerable depression and fracture in the floor covering (see table 1 and fig. 16); otherwise the floor covering presented a more even surface than is usually obtained on a strip-wood subfloor. The enamel surfaces of the floor coverings were worn through in spots by the walking wheel in approximately 30,000 cycles, or 6,000 cycles after the wheel had been covered with abrasive cloth. The total depth of wear is shown in table 2.

The felt-base floor covering with a wearing surface consisting of a resin-treated cotton-linters sheet, panels *7L* and *8R*, withstood the test very well. Along the path of the steel-tired truck wheel there was some failure in adhesion to the concrete subfloor and slight fracture of the floor covering (see fig. 17). On a Douglas fir plywood subfloor, panel *8R*, the steel-tired truck wheel caused appreciable depression and slight fracture in the floor covering (see table 1 and fig. 18). The wearing surface showed good resistance to abrasion.

The 5/64-in. and the 7/64-in. felt-base tiles with a wearing surface consisting of a cellulose nitrate composition, panels *9L*, *10L*, *9R*, and *10R*,

FIGURE 3.—⅛-*in. marbleized linoleum on concrete subfloor (test panel 1L).*

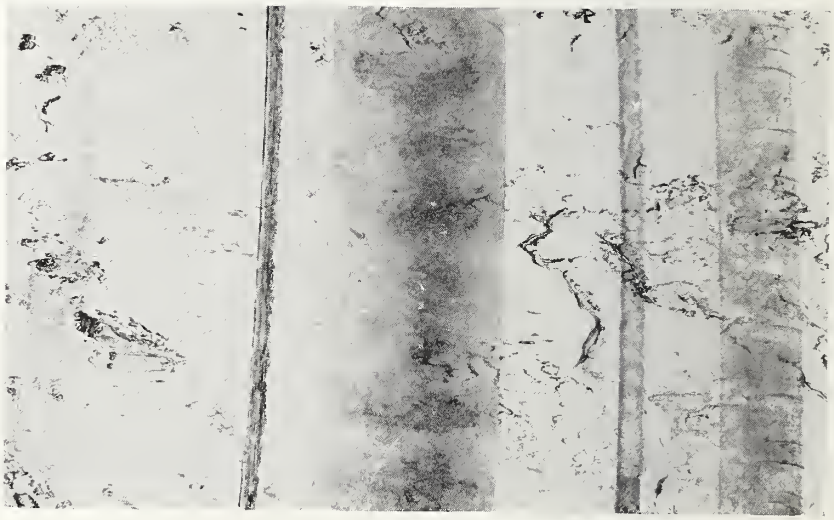

FIGURE 4.—⅛-*in. marbleized linoleum on strip-wood subfloor (test panel 2L).*

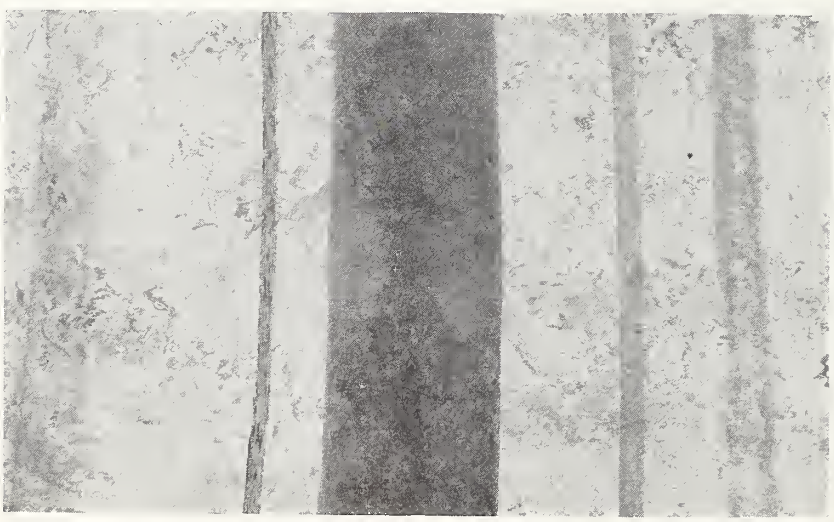

FIGURE 5.—⅛-*in. marbleized linoleum on concrete subfloor (test panel 1R).*

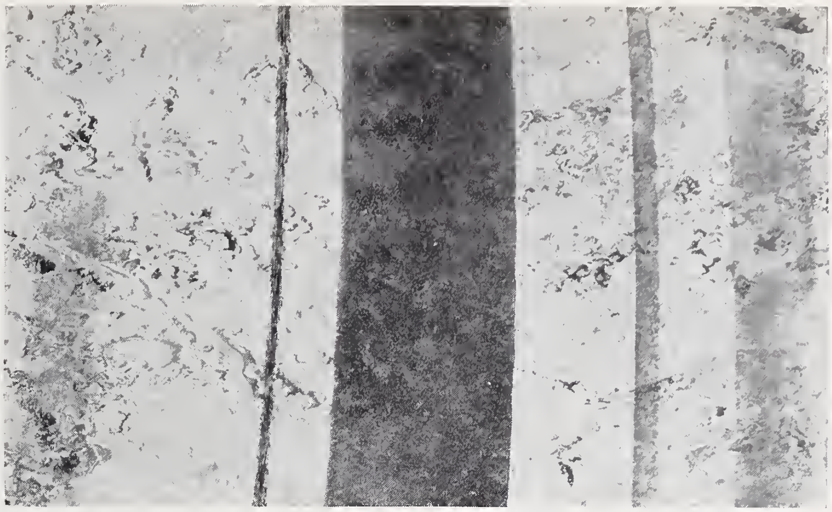

FIGURE 6.—⅛-in. *marbleized linoleum on strip-wood subfloor (test panel 2R).*

FIGURE 7.—⅛-in. *linoleum tile on concrete subfloor (test panel 3R).*

FIGURE 8.—⅛-in. *linoleum tile on strip-wood subfloor (test panel 4R).*

FIGURE 9.—⅛-in. *cork-composition tile on concrete subfloor (test panel 3L).*

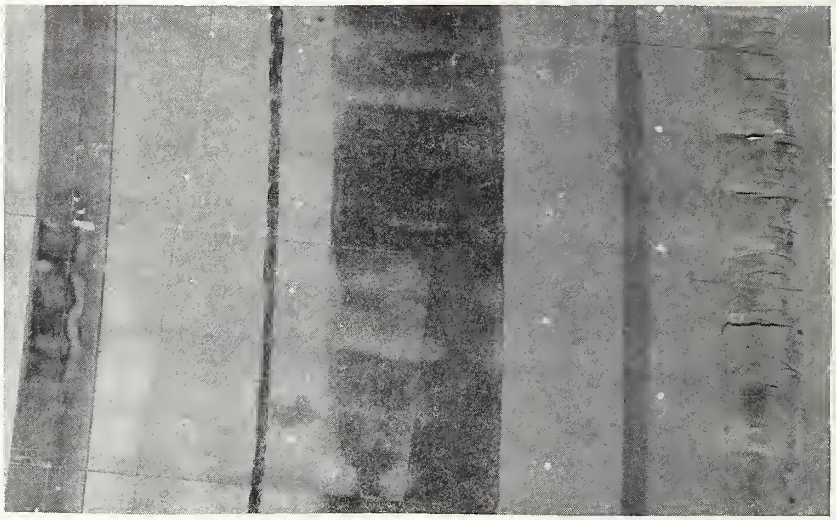

FIGURE 10.—⅛-in. *cork-composition tile on strip-wood subfloor (test panel 4L).*

FIGURE 11.—⅛-in. *sheet rubber on concrete subfloor (test panel 5L).*

FIGURE 12.—⅛-in. *rubber tile on concrete subfloor (test panel 5R).*

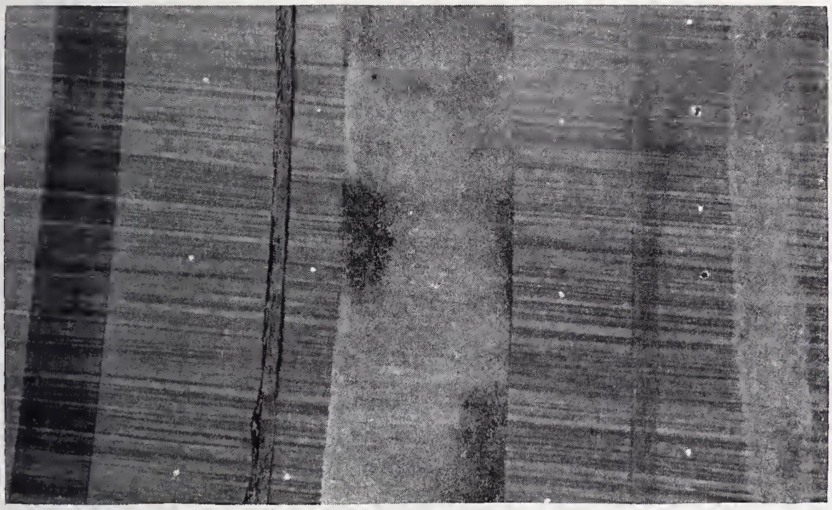

FIGURE 13.—³⁄₃₂-in. *jaspe linoleum on concrete subfloor (test panel 6L).*

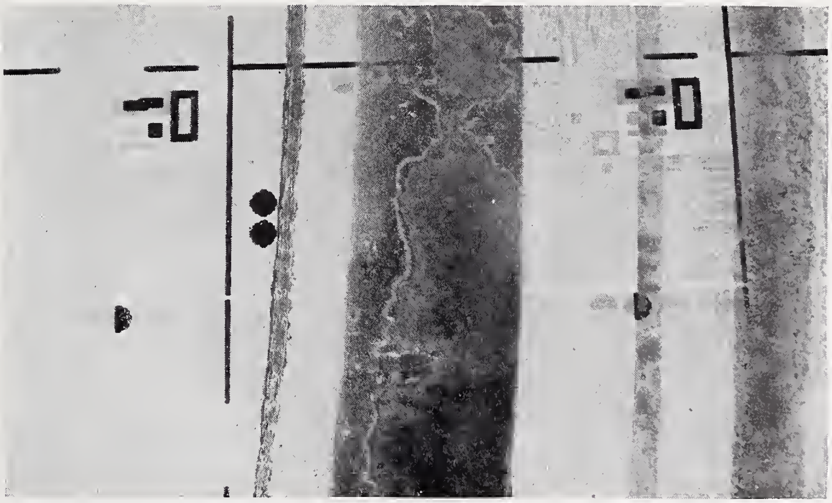

FIGURE 14.—⁵⁄₆₄-in. *felt base, enamel wearing surface, on concrete subfloor (test panel 6R).*

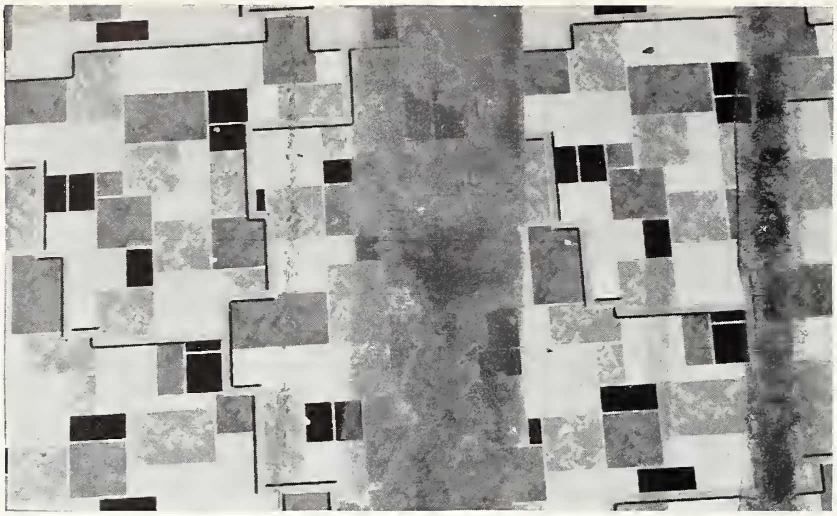

FIGURE 15.—$\frac{5}{64}$-*in. felt base, enamel wearing surface, on concrete subfloor (test panel 7R).*

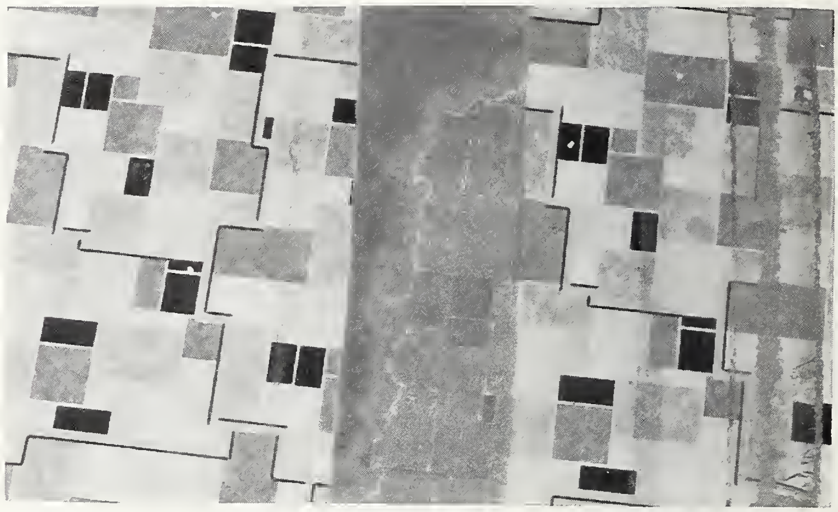

FIGURE 16.—$\frac{5}{64}$-*in. felt base, enamel wearing surface, on plywood subfloor (test panel 8L).*

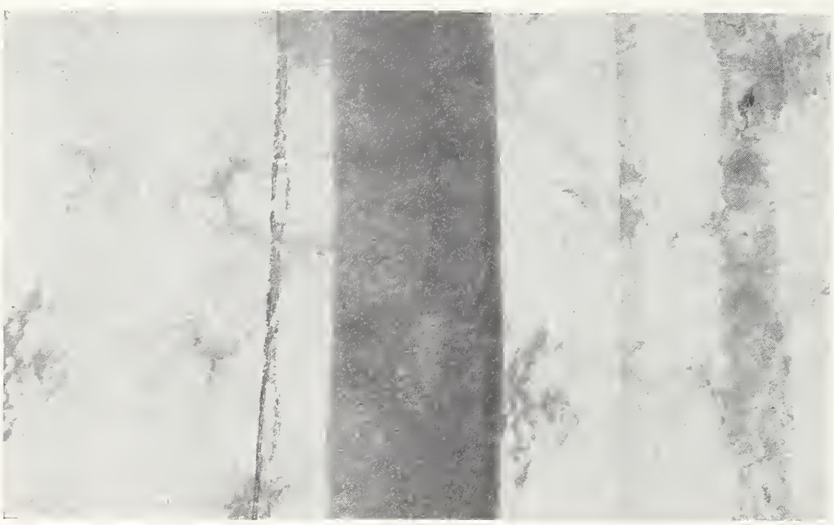

FIGURE 17.—$\frac{5}{64}$-*in. felt base, resin treated cotton linters sheet wearing surface, on concrete subfloor (test panel 7L).*

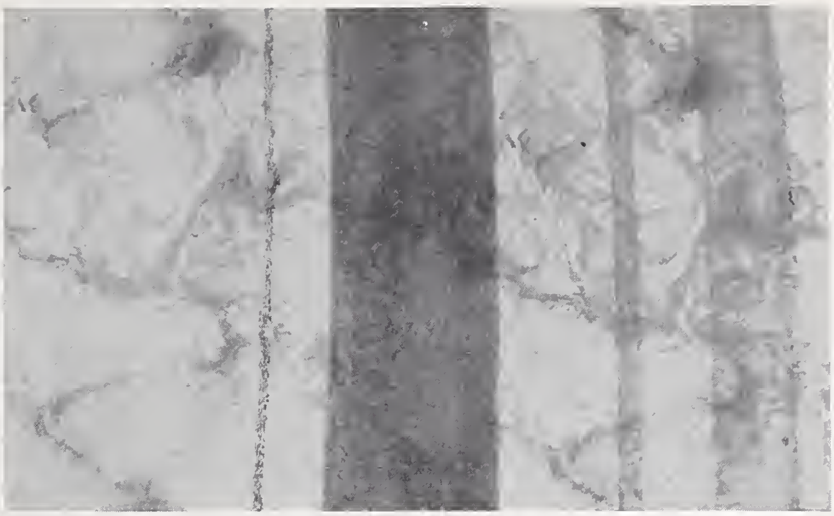

FIGURE 18.—$\frac{5}{64}$-*in. felt base, resin treated cotton linters sheet wearing surface, on plywood subfloor (test panel 8R).*

FIGURE 19.—$\frac{5}{64}$-*in. felt-base tile, cellulose nitrate composition wearing surface, on concrete subfloor (test panel 9L).*

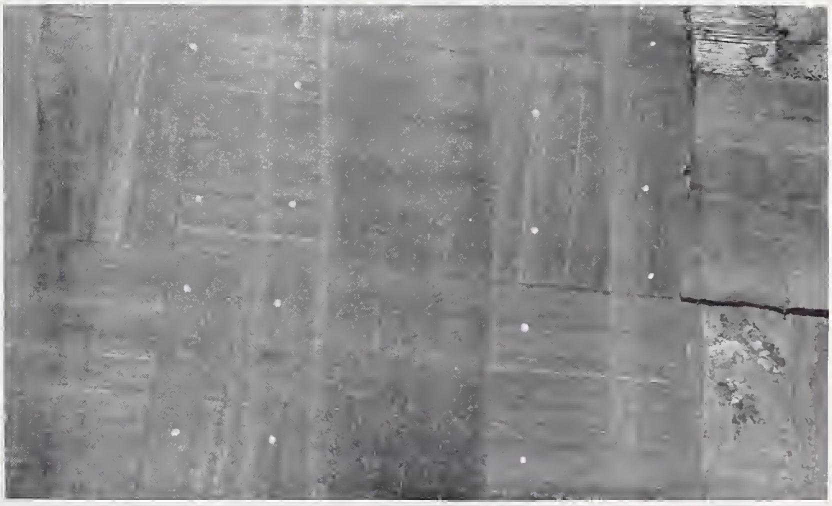

FIGURE 20.—$\frac{5}{64}$-*in. felt-base tile, cellulose nitrate composition wearing surface, on strip-wood subfloor (test panel 10L).*

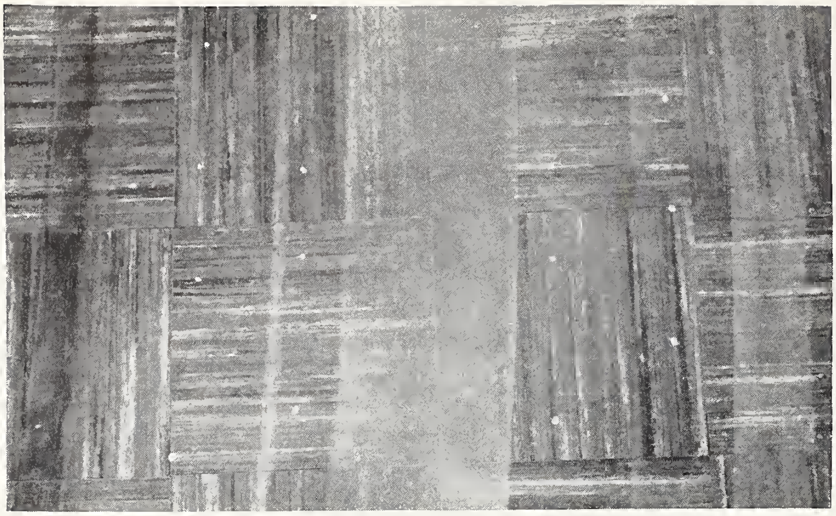

Figure 21.—7/64-*in. felt-base tile, cellulose nitrate composition wearing surface, on concrete subfloor (test panel 9R).*

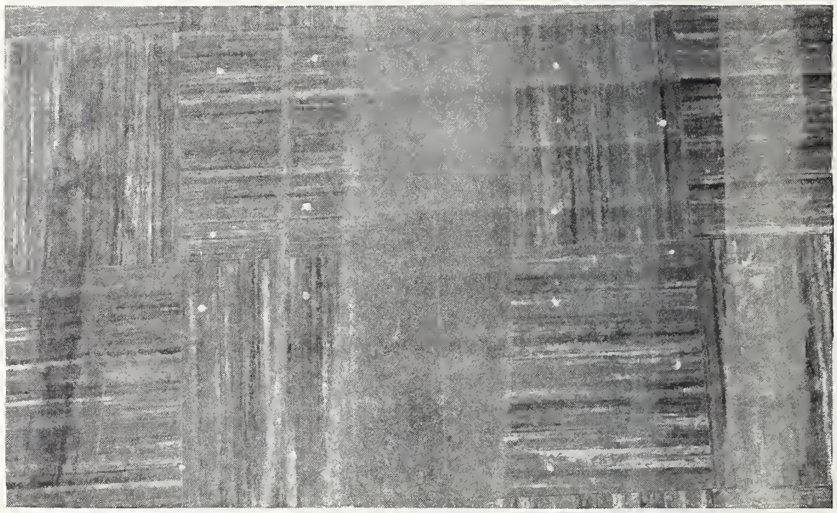

Figure 22.—7/64-*in. felt-base tile, cellulose nitrate composition wearing surface, on stripwood subfloor (test panel 10R).*

Figure 23.—1/8-*in. asphalt tile on concrete subfloor (test panel 11L).*

FIGURE 24.—⅛-in. asphalt tile on concrete subfloor (test panel 11R).

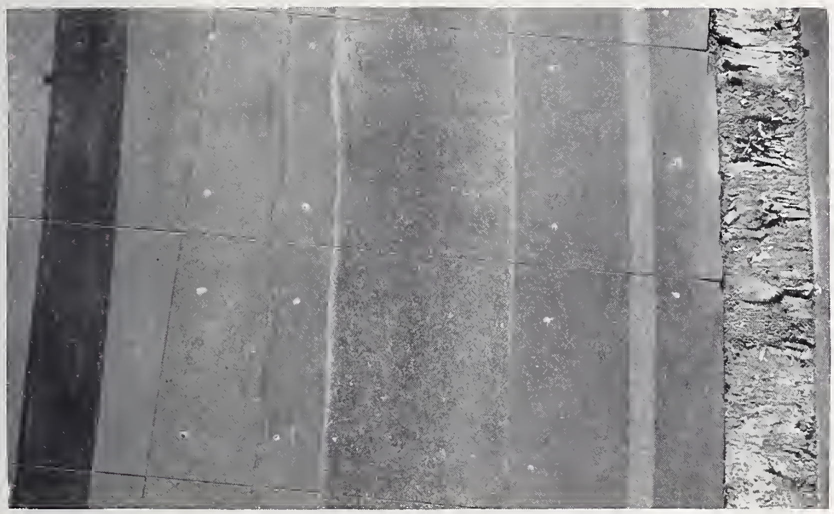

FIGURE 25.—⅛-in. asphalt tile on plywood subfloor (test panel 12L).

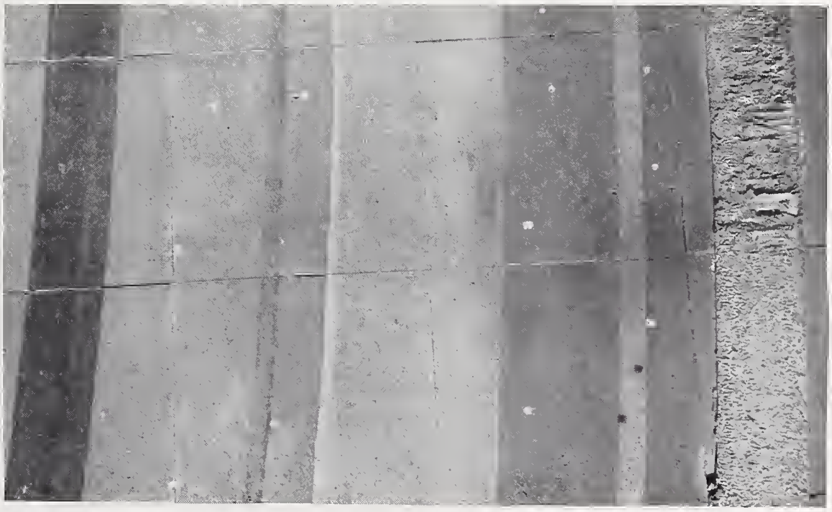

FIGURE 26.—⅛-in. asphalt tile on plywood subfloor (test panel 12R).

Figure 27.—$\frac{3}{16}$-*in. asphalt tile on concrete subfloor (test panel 13L).*

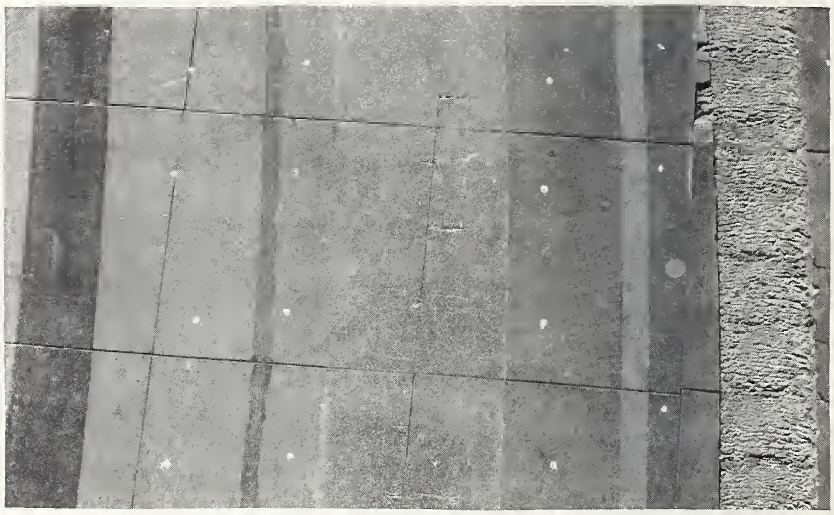

Figure 28.—$\frac{3}{16}$-*in. asphalt tile on strip-wood subfloor (test panel 14L).*

Figure 29.—$\frac{3}{16}$-*in. asphalt tile on concrete subfloor (test panel 13R).*

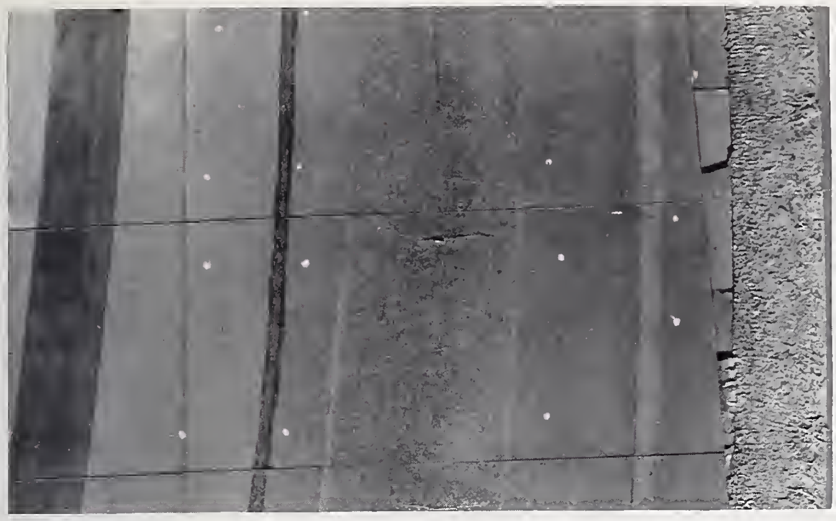

FIGURE 30.—$\frac{3}{16}$-*in. asphalt tile on strip-wood subfloor (test panel 14R).*

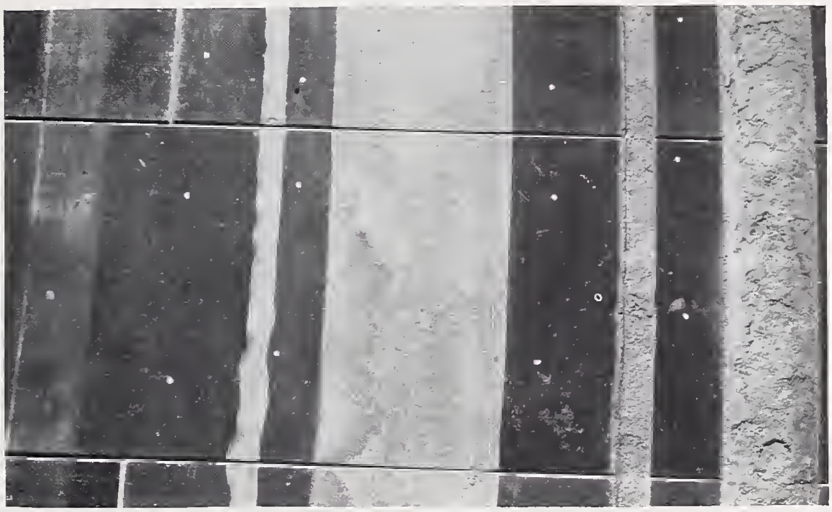

FIGURE 31.—$\frac{1}{4}$-*in. asphalt-impregnated fiberboard tile on concrete subfloor (test panel 15L).*

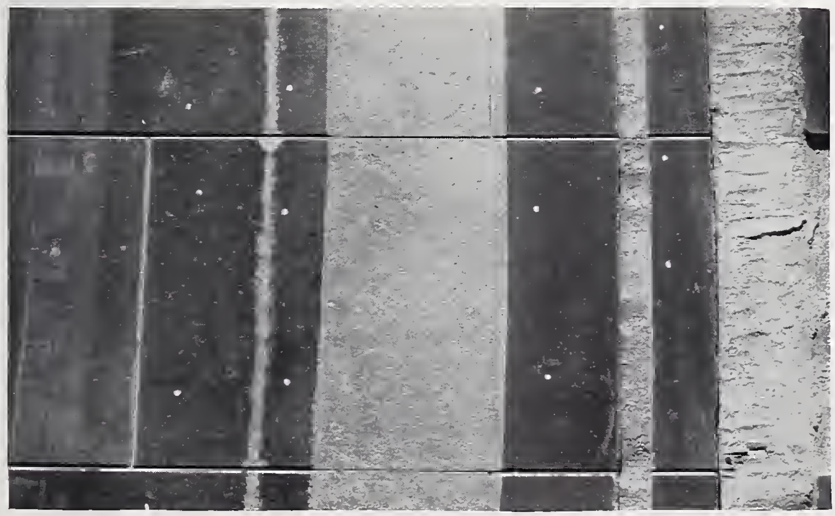

FIGURE 32.—$\frac{1}{4}$-*in. asphalt-impregnated fiberboard tile on plywood subfloor (test panel 16R).*

FIGURE 33.—¼-*in. asphalt-impregnated fiberboard tile on concrete subfloor (test panel 15R).*

FIGURE 34.—$^{25}/_{32}$-*in. strip Douglas fir on wood sleepers (test panel 16L).*

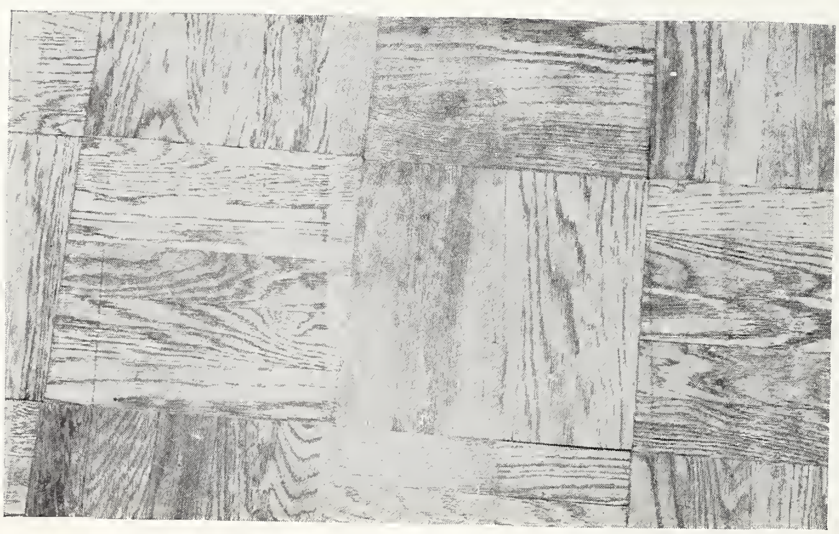

FIGURE 35.—½-*in. white-oak unit-block on concrete subfloor (test panel 17L).*

FIGURE 36.—½-in. red-oak unit-block on strip-wood subfloor (test panel 18L).

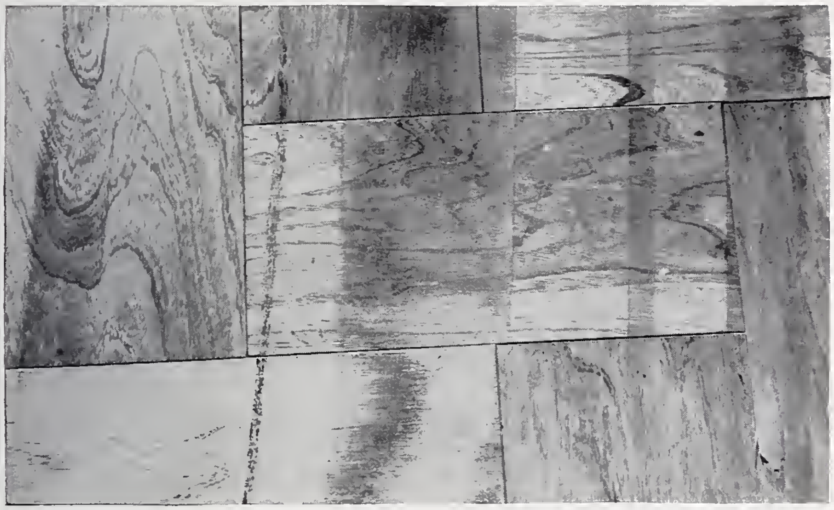

FIGURE 37.—½-in. rock-elm plywood tile on concrete subfloor (test panel 17R).

FIGURE 38.—⅜-in. rock-elm plywood tile on fiber mat and strip-wood subfloor (test panel 18R).

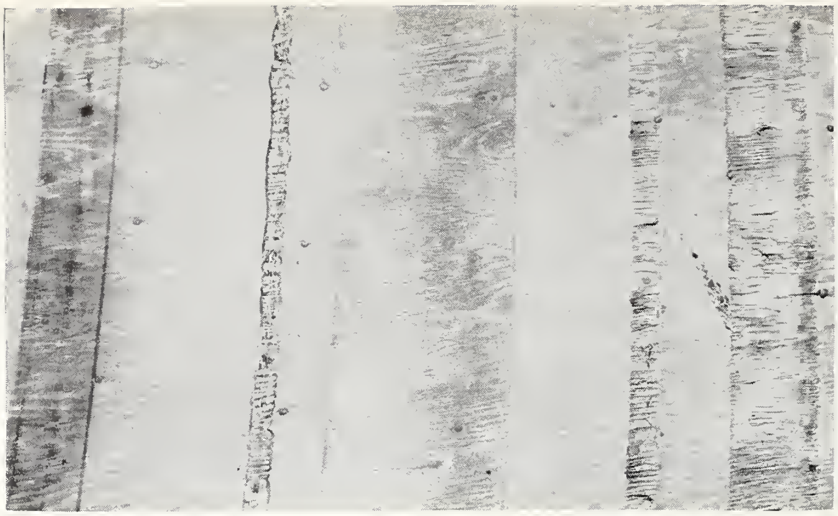

FIGURE 39.—½-*in. Douglas-fir plywood on strip-wood subfloor (test panel 19L).*

FIGURE 40.—½-*in. magnesium-oxychloride composition on strip-wood subfloor (test panel 19R).*

FIGURE 41.—½-*in. alumina cement-latex composition on concrete subfloor (test panel 20R).*

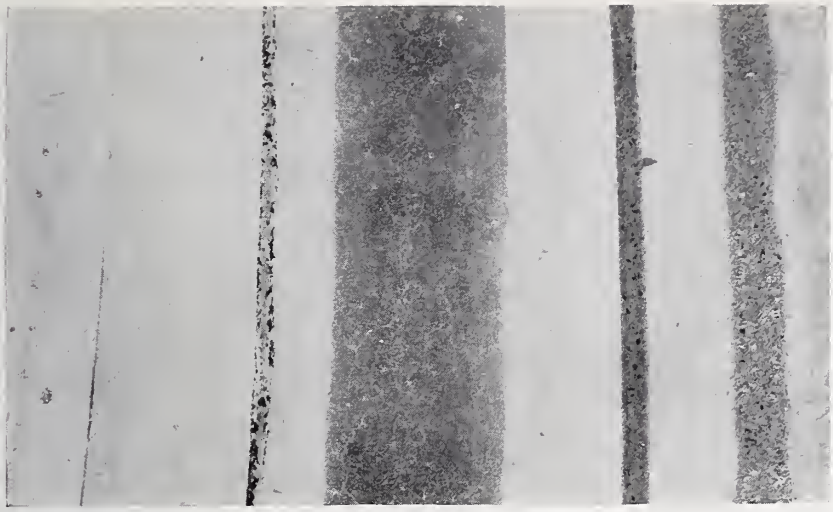

FIGURE 42.—*1-in. cement-mortar topping, 1:2 mix, on concrete subfloor (test panel 20L).*

withstood the test very well, with the possible exception of panel *10L* (see figs. 19, 20, 21, and 22). On a strip-wood subfloor with a dry lining felt, panel *10L*, the steel-tired truck wheel caused separation in the lining felt and displaced some of the tiles (see fig. 20). On a strip-wood subfloor with no lining felt, panel *10R*, the $\frac{7}{64}$-in. tiles were moderately fractured by the steel-tired truck wheel (see fig. 22). Ridges caused by the strip-wood subfloor showed on the surface of the $\frac{7}{64}$-in. tiles with no underlay whereas they did not show on the surface of the $\frac{5}{64}$-in. tiles with a felt underlay (compare figs. 20 and 22). The wearing surface of the tiles showed good resistance to abrasion.

The $\frac{1}{8}$-in. and the $\frac{3}{16}$-in. asphalt tiles showed fair performance on a concrete subfloor (see figs. 23, 24, 27, and 29). They were pitted and worn to a moderate degree by the steel-tired truck wheel (see table 1). The $\frac{1}{8}$-in. asphalt tiles on Douglas fir plywood subfloors with no underlay, panels *12L* and *12R*, showed fair performance except under the action of the steel-tired truck wheel, which crushed the tiles completely (see figs. 25 and 26). The $\frac{3}{16}$-in. asphalt tiles on a strip-wood subfloor with an underlay of felt, panels *14L* and *14R*, did not stand up well in this test. The tiles were crushed by the steel-tired truck wheel and were fractured to an appreciable degree by the walking wheel (see figs. 28 and 30). In general, the asphalt tiles were worn to a moderate degree by the abrasive action of the walking wheel (see table 2).

The $\frac{1}{4}$-in. asphalt-impregnated fiberboard tiles, panels *15L*, *16R*, and *15R*, were in unserviceable condition at the end of the performance test. They were pitted and worn to a considerable degree by both the steel-tired truck wheel and the steel-wheel caster (see table 1 and figs. 31, 32, and 33). The painted surface of the tiles was worn through by the walking wheel in approximately 30,000 cycles, or 6,000 cycles after the application of the abrasive cloth. The total depth of wear is shown in table 2.

The strip Douglas fir, panel *16L*, was in unsatisfactory condition at the end of the test. The flooring was indented and splintered to an appreciable degree by both the steel-tired truck wheel and the steel-wheel caster (see table 1 and fig. 34). The Douglas-fir strip flooring showed poor resistance to abrasion.

The white-oak and the red-oak unit-blocks, panels *17L* and *18L*, showed good performance. The unit-blocks were moderately compressed, and were fractured or splintered to a slight extent, by the steel-tired truck wheel (see table 1 and figs. 35 and 36). There was no evidence of failure in bond to the subfloors, although the individual strips in the unit-blocks showed a slight tendency to warp. The white-oak unit-blocks showed slightly better resistance to abrasion than the red-oak unit-blocks (see table 2).

The $\frac{1}{2}$-in. and the $\frac{3}{8}$-in. Rock-elm plywood tiles, panels *17R* and *18R*, were in good condition at the end of the test. The tiles were

moderately compressed by the steel-tired truck wheel (see table 1). There was no appreciable fracturing or splintering of the tiles (see figs. 37 and 38). The ½-in. tile showed better resistance to abrasion than the ⅜-in tile (see table 2). The ½-in. tiles showed a slight tendency to warp, and they were not in complete contact with the concrete subfloor over the entire area of the test panel. The ⅜-in. tiles laid over a ¼-in. rubberized sisal-fiber mat were held together very well by the metal dowel pins but were noisy when walked upon.

The ½-in. Douglas-fir plywood, panel *19L*, remained in fair condition throughout most of the test, although at the end it was in unsatisfactory condition. The plywood was indented and splintered to an appreciable degree by both the steel-tired truck wheel and the steel-wheel caster (see table 1 and fig. 39). The splintered condition did not occur until near the end of the test. The Douglas-fir plywood showed fair resistance to abrasion (see table 2).

The ½-in. magnesium-oxychloride composition floor reinforced with expanded metal, panel *19R*, did not show satisfactory performance on a strip-wood subfloor. The floor was pitted and worn appreciably by the steel-tired truck wheel (see table 1 and fig. 40). A fine crack developed in the floor along the entire path of the walking wheel (see fig. 40). The floor showed only fair resistance to abrasion (see table 2).

The ½-in. alumina cement-latex composition floor, panel *20R*, showed unsatisfactory performance. The surface was depressed appreciably by the steel-tired truck wheel and was also depressed to a moderate degree by the rubber-tired truck wheel and the leather-shod walking wheel (see table 1 and fig. 41). There was no evidence of fracture in the floor and bond to the concrete subfloor was excellent. The floor was worn to an appreciable degree by the abrasive action of the walking wheel (see table 2).

The 1-in. cement-mortar topping, panel *20L*, showed good performance. The topping was pitted and worn to a slight degree by the steel-tired truck wheel (see table 1 and fig. 42). The fine cracks showing along the path of the walking wheel are due to internal shrinkage of the topping. The topping showed fair resistance to abrasion (see table 2).

## VII. COMMENTS AND CONCLUSIONS

Physical properties of floor coverings which should be considered and which have a bearing on their performance and durability in service are resistance to abrasion, resistance to tear and fracture, indentation characteristics, dimensional changes with change in atmospheric conditions, and resistance to cleansing and finishing materials. Floor coverings should be allowed to come to a moisture and temperature equilibrium normal to the location before being installed in order to minimize the effect of dimensional changes after installation.

In order to obtain a satisfactory installation of a floor covering, a number of factors must be considered in addition to the physical properties essential to all floor coverings. A dry, even, rigid, and clean subfloor is necessary for most floor coverings. A subfloor should be thoroughly inspected for these requirements and appropriate alterations made where needed. New concrete subfloors should be allowed to dry thoroughly before installing a floor covering. Over a strip-wood subfloor an underlay of lining felt is beneficial to thin floor coverings. Dry lining felt can be readily removed from the subfloor whereas the removal of asphalt-saturated felt is difficult. Where traffic conditions are

severe, especially trucking, dry lining felt is likely to separate in itself. Asphalt-saturated lining felt is considered preferable under such conditions. Douglas-fir plywood used as a subfloor furnishes an even surface, which is especially desirable for thin floor coverings or those which fracture readily. Where traffic or loads are likely to be heavy, a subfloor of lower compressibility would be necessary.

Many types of floor coverings need to be bonded to a subfloor. A failure in the bond is very likely to result in pronounced failure in the floor covering. Failure of a bond may result from an unclean or wet condition of the subfloor, separation in an underlay, a faulty adhesive or method of installation, or from excessive dimensional changes of a floor covering with changes in relative humidity and temperature.

In interpreting the results of this and the two previous performance tests [2, 3], it should be realized that the tests were greatly accelerated and represent very severe service. In the selection of a floor covering and method of installation, the nature of the exposure to which the floor will be subjected, the desires of the occupant as to appearance and comfort, and the service per unit of total cost (initial and maintenance or renewal) are of importance. In this respect, some of the lower-cost floor coverings and methods of installation, even though less durable, may render economical and satisfactory service for some types of occupancy.

## VIII. SELECTED REFERENCES [2]


[1] Federal specifications for floor coverings:

| *Title* | *Symbol* | *Price* |
|---|---|---|
| Linoleum; battleship | LLL-L-351 | 5¢ |
| Linoleum; plain, inlaid, and printed | LLL-L-361 | 5¢ |
| Carpet; cork | LLL-C-96 | 5¢ |
| Tile; cork | LLL-T-431 | 5¢ |
| Tile; asphalt | SS-T-306 | 5¢ |
| Tile; floor, rubber | ZZ-T-301 | 5¢ |
| Floor-covering; rubber, sheet | ZZ-F-461 | 5¢ |
| Matting; rubber | ZZ-M-71 | 5¢ |

[2] P. A. Sigler and E. A. Koerner, Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1, NBS Building Materials and Structures Report BMS34 (1940). 10¢.

[3] P. A. Sigler and E. A. Koerner, Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 2, NBS Building Materials and Structures Report BMS43 (1940). 10¢.

[4] W. E. Emley and C. E. Hofer, *Test of floor coverings for post-office workrooms*, J. Research NBS 19, 567 (1937) RP1046. 10¢.

[5] P. A. Sigler and Myrtle B. Woodward, Indentation and Recovery of Low-Cost Floor Coverings, NBS Building Materials and Structures Report BMS14 (1939). 10¢.

[6] P. A. Sigler and R. I. Martens, Properties of Adhesives for Floor Coverings, NBS Building Materials and Structures Report BMS59 (1940). 10¢.


WASHINGTON, October 5, 1940.

[2] Articles may be purchased from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., at the prices indicated.

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| BMS24 | Structural Properties of a Reinforced-Brick Wall Construction and a Brick-Tile Cavity-Wall Construction Sponsored by the Structural Clay Products Institute | 10¢ |
| BMS25 | Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs | 15¢ |
| BMS26 | Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Co., Inc. | 10¢ |
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